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EXPERIMENTAL INVESTIGATIONS OF THE INFLUENCE OF ABLATION TO THE PRESSURE BUILD-UP IN SF_6 SELF-BLAST CIRCUIT BREAKERS

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ABSTRACT

This paper deals with the arc extinction of a commercial SF_6 self-blast circuit-breaker. For studies, signals from switching off operations with varying electrical parameters and under no-load conditions were compared using PTFE parts as well as non-gassing modules. This allows a better understanding of the influence of the ablation and gassing effect to the arc behaviour and to the pressure build-up in the arc extinction system. Pressure sensors were installed at different points inside the interrupter unit of a high-voltage circuit breaker. Additionally transient signals of mechanical and electrical sensors were recorded in parallel to the pressure signals. The non-gassing nozzles were constructed with the same geometry as the original PTFE nozzles to realize comparable flow conditions.

Index Terms - SF_6 self-blast circuit breaker, pressure measurement, arc extinction, PTFE ablation effect

1. INTRODUCTION

Arc interruption with a high-voltage circuit breaker is a complex process. The arc extinction is only successful, if a lot of physical processes collude conveniently. The switching off operation is made up by the mechanical operation, the build-up of the quenching gas pressure, the arc process and its contribution to the pressurisation, the flow characteristics and the dielectric strength of the switching gap after current zero. These physical processes are not independent, but rather they interact during the switching off operation and affect each other.

For the investigation of the ablation effect experiments regarding mainly the mass loss and volume ablation were carried out on circuit breaker models as well as on the original circuit breaker setups [1, 2]. In our research gas pressure measurements were carried out at significant points of the interrupter unit (IU) to show the influence of the PTFE ablation effect on the pressure values. This effect was investigated for different arc energy inputs, with and without ablation effect. Furthermore, the influence of the energy input on the interaction between the kinematic chain and the plasma arc stressed contact system is analysed. All measurements were performed with a commercially available SF_6 self-blast circuit-breaker.

2. MEASUREMENT SYSTEM

For holistic considerations of all relevant physical effects at switching off process, important electrical parameters and essential mechanical values were measured as time-dependent signals. Fig.1 shows the mechanical equivalent circuit of the switchgear with the corresponding measuring points. The movement of the IU is realised by a spring drive mechanism, whose travel-characteristic is detected by potentiometer. To determine the contact movement, this measured signal has to be converted. To get more information about the interaction between the spring drive and the IU a force sensor is established at the operating rod. A piezoelectric sensor is used for this signal.

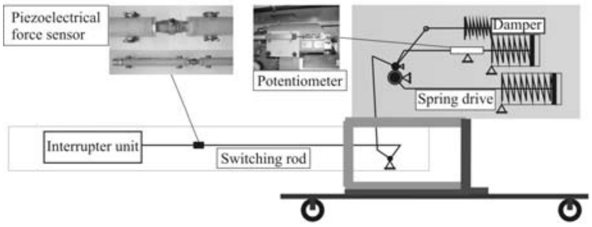

Fig. 1: Measuring points at the kinematic chain

The main focus of this investigation are the measurements of time-dependent pressure signals at different places inside of the IU. The positions of the measuring points are presented in Fig.2.

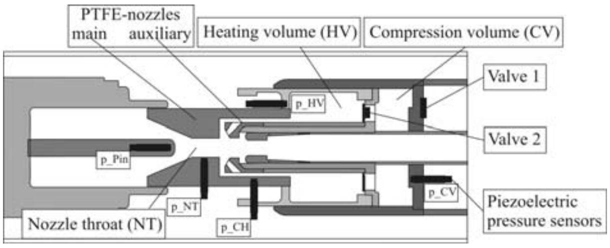

Fig. 2: Measuring points inside the IU

The pressure curves are recorded at five significant points. With the knowledge of the pressure signal inside the different volumes it is possible to draw conclusions about the flow characteristics and the pressure build-up. To ensure an adequate gas flow during the switching off process two pressure controlled valves arranges the pressurisation in the heating volume (HV) and the compression volume (CV). The information of the state of the valves leads to a better understanding of the running processes during the switching off operation.

3. ANALYSIS OF THE SWITCHING OFF PROCESS WITH SENSOR SIGNALS

The measurements are only done for switching off processes. Thereby, the opening spring accelerates the kinematic chain and this leads to movement of the IU. So the contact opens and the arc ignites. Over the whole opening movement, the CV (Fig.2) is reduced and the gas inside of the volume is compressed. The outcome of this is a gas flow from the CV to the HV when the valve 2 is opened, leading to a pressure rise in the HV. Due to the arc power the pressure in the NT increases too. Because of that, a big amount of the hot gas flows from the NT into the HV, parallel to the cold gas from the CV where it is getting mixed. As a consequence, the pressure inside the HV further increases. In the range of current zero a backflow begins from the HV to the NT, because of the induced pressure gradient. Because of this gas flow, the arc is blown and cooled. When the arc extinguishes at the current zero crossing, the back flowing gas deionises and strengthen the switching gap at a successful switching performance. This simplified switching process of a self-blast circuit breaker is highly dependent from the inputted arc energy. One example of a measurement result, which shows the influence of the arc energy to some physical processes and especially the reaction to the drive mechanism, is allegorised in Fig.3a and Fig.3b.

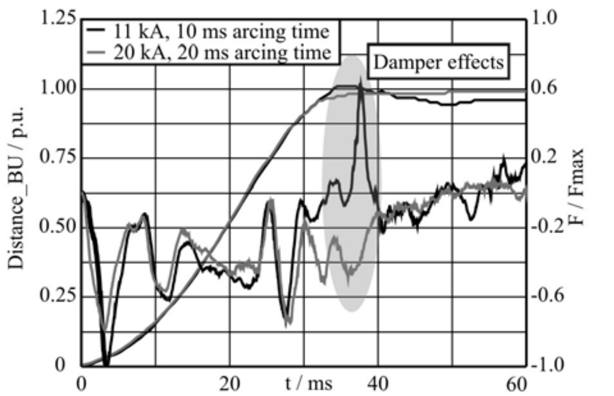

Fig. 3a: Force signals and distance-time-characteristics of the IU

In Fig.3a the force signals measured at the switching rod and the distance-time-characteristics of the IU at two different energy inputs are presented. The comparison of the force signals between 30 ms and 40 ms shows a different behaviour. It can be seen, that at 20 kA_{rms} the characteristic impact force at the end of the opening process caused by the damper reaction is not effective. That means that with a high switching energy, the mechanical operation at the end of the movement is more damped. The reason for that can be explained by comparing the respective pressure signals inside the HV and CV (Fig.3b).

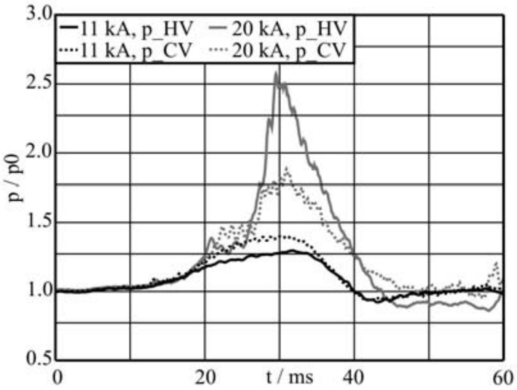

Fig. 3b: Comparison of the pressure signals inside the HV and CV

At the lower arc energy input the maximum pressure in the CV is higher than in the HV, which means that valve 2 is opened and valve 1 is closed. At the higher energy input there is a big pressurisation in the NT whereby also the pressure in the HV increases and getting higher than the pressure in the CV at approx. 26 ms. Thereby valve 2 closes. As an effect the gas in the CV is getting more and more compressed by the opening operation. To enable the movement furthermore, valve 1, which is getting controlled by a defined counterforce, must open to realise the expanding of the gas inside the CV. This causes a higher effort of the drive unit. The result is a more damped switching off process for the mechanical part. A detailed description of the valve function is included in [3].

4. ABLATION AND PRESSURE BUILD-UP

Due to the ablation effect of the PTFE nozzle, the pressure build-up and cooling effects are additionally supported for high energy inputs. With the comparison of the pressure curves and the maximum pressure values by the variation of inputted arc energy and nozzle material, useful expertise about the influence of the ablation effect to the pressure conditions in the IU was found. Therefore an auxiliary nozzle and a main nozzle without ablation effect were used. Both nozzles have the same inner geometry as the original PTFE nozzles to ensure identical gas flow geometries. With the combination of the different main and auxiliary nozzles, it is possible to create four different nozzle variations, so the influence of both nozzles to the pressure build-up based on the ablation effect can be determined separately. With these investigations it was found, that the pressurisation inside the IU is influenced by the ablation effect of the PTFE material at currents higher than 12 kA_{rms} with an arcing time of 20 ms. Fig.4a and Fig.4b show the comparison of the pressure curves in the CV, HV and NT at a short-circuit current of 14 kA_{rms} with an arcing time of 20 ms. The original nozzle configuration was used for the first test and for the second test the PTFE main nozzle was replaced by a nozzle without ablation effect.

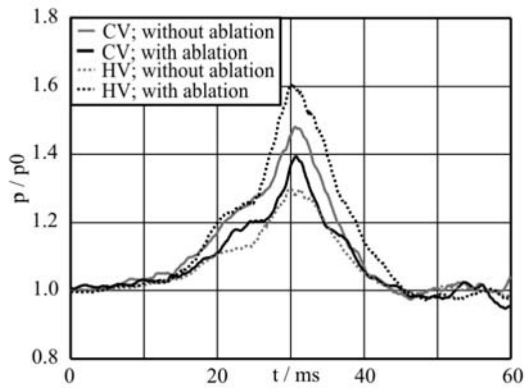

Fig. 4a: Pressure signals in the HV and CV at 14 kA_{rms}, 20 ms arc

The comparison of the pressure curves from the CV and the HV reveal, that the ablation effect of the main nozzle has a bigger influence to the pressure in the HV. Using the PTFE main nozzle the pressure maximum in the HV is 30 % higher than the maximum pressure in HV using the main nozzle without the ablation effect. On the contrary to this, the pressure maximum in the CV is much smaller for the PTFE-nozzle than for the case with the main nozzle without ablation effect. The reason for this is that due to the ablation effect with the PTFE nozzle configuration, the pressure inside the HV increases to higher values than the pressure inside the CV at a certain arc energy input. So, valve 2 closes between both volumes and separates them from each other. In the measurements, the nozzle without ablation effect always results in higher pressure values inside the CV than the HV pressure, what means that valve 2 is opened over the whole switching process and the compression of the gas inside the CV accounts essentially to the arc extinction.

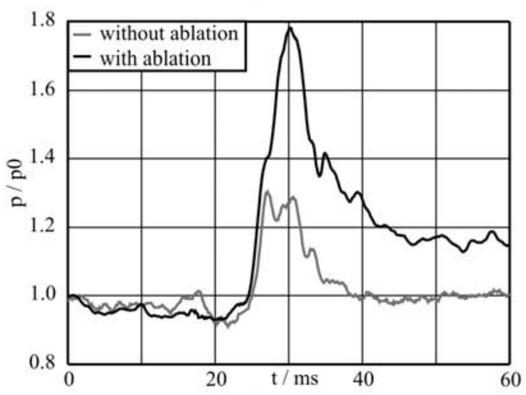

Fig. 4b: Pressure signals inside the NT at 14 kA_{rms}, 20 ms arc

Indeed, the ablation effect has the biggest influence to the pressure rates in the NT, as it is shown in Fig.4b. Here, the maximum pressure value in the measurement with PTFE main nozzle is approx. 50 % higher than the pressure maximum at the switching off process with the ablation free nozzle by comparable arc energy input.

5. CONCLUSION

To get a better understanding of the gas flow and pressure rise during the arc extinction of a self-blast circuit breaker, sensors were installed at significant points of a commercial high-voltage circuit breaker. In addition to the pressure signals at relevant points of the interrupter unit, mechanical and electrical signals were measured. The results of this investigation give a better understanding about the pressure and flow profile for the arc extinction and the interaction between the drive and the interrupter unit. With the use of gassing and non-gassing nozzle material and the variation of the inputted arc energy, important expertise to the influence of the ablation effect at the switching process and especially the pressure build-up in essential volumes of the IU were obtained.

6. REFERENCES

[1] Müller, L.: Modelling of an ablation controlled arc, J. Phys. D: Appl. Phys. 26 (1993)

[2] Seeger, M.; Tepper, J., et al.: Experimental investigation on PTFE ablation in high voltage circuit breakers, XVIth Symposium on Physics of Switching Arc, 2005

[3] Reichert, F.; Kornhaas, A., et al.: Simulation of interaction between switching arc and switching mechanics in SF6 self-blast circuit breakers, XVIIIth Symposium on Physics of Switching Arc, 2009